THE AQUATIC PLANT COMMUNITY OF FRIENDSHIP LAKE, ADAMS COUNTY, WISCONSIN

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Submitted by Reesa Evans
Adams County Land & Water Conservation Department
P.O. Box 287, Friendship, WI 53934
608-339-4268

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ADAMS COUNTY 2006

I. INTRODUCTION

An updated aquatic macrophytes (plants) field study Friendship Lake was conducted during August 2006 by a staff member the Adams County Land and Water Conservatism Department.

Information about the diversity, density and distribution of aquatic plants is an essential component in understanding the lake ecosystem due to the integral ecological role of aquatic vegetation in the lake and the ability of vegetation to impact water quality (Dennison et al, 1993). This study will provide information useful for effective management of Friendship Lake, including fish habitat improvement, protection of sensitive areas, aquatic plant management, and water resource regulation. This baseline data will provide information that can be used for comparison to future information and offer insight into changes in the lake.

Ecological Role: Lake plant life is the beginning of the lake's food chain, the foundation for all other lake life. Aquatic plants and algae provide food and oxygen for fish and wildlife, as well as cover and food for the invertebrates that many aquatic organisms depend on. Plants provide habitat and protective cover for aquatic animals. They also improve water quality, protect shorelines and lake bottoms, add to the aesthetic quality of the lake, and impact recreation.

Characterization of Water Quality: Aquatic plants can serve as indicators of water quality because of their sensitivity to water quality parameters such as clarity and nutrient levels (Dennison et al, 1993).

Friendship Lake readings for hardness and pH score its water as "moderately hard" to "hard", with the pH running between 6.5 and 9.0. Such lakes tend to produce more fish and aquatic plants than soft water lakes.

Background and History: Friendship Lake is located in the Town of Adams, Adams County, Wisconsin. The impoundment is 115 surface acres in size. Maximum depth is 16', with an average depth of 6'. During the summer of 2006 when this aquatic plant survey was conducted, the lake was at slightly lower level than usual due to drought and very hot weather. The dam impounds Little Roche a Cri Creek. There is a public boat ramp located on north side of the lake owned by The Adams County Parks Department, as well as a public swimming beach.

Friendship Lake is easily accessible off of State Highway 13. Residential development around the lake is found along most of the lakeshore, except for the far east end, where it is located mainly on the north shore. The surface watershed is 6.21% residential; 11.4% non-irrigated agriculture; 43.7% irrigated agriculture; 35.69% woodlands; 1.15% industrial/commercial; 1.15% open grassland; .16% transportation; and 1.87% water. The ground watershed, which extends into Waushara County, contains 11.43% non-irrigated agriculture; 29.06% irrigated agriculture; 45.29% woodlands; 9.56% residential; .16% industrial/commercial; .19% transportation; .6% open grassland; and 3.68% water. There are endangered or threatened aquatic and terrestrial resources in both the

surface and ground watersheds, but no known endangered or threatened species in or directly around the lake. A small dredging project occurred in 1987.

There are several archeological sites in the surface watershed: (1) Rocky Bluff Village, a Native American village site, now mostly under water; (2) Frank McConick Mound Group of burial effigies, including a short-tailed animal, a bear and some linear mounds; (3) a home site from the late 19th century. There are also various historical sites, including the 8th Avenue Bridge.

Fish stocking records go back to 1933 when walleye and black bass were stocked in the lake. Stocking records through the 1950s show continued stocking of bass, bluegills, perch, pike and walleye, with one stocking of bullheads. There was a chemical fish removal in 1984 of over 20,000 bluegills, along with some 2000+ perch, 1600+ crappie and 1400+ pumkpkinseeds. The most recent fish inventory in 2002 showed the largemouth bass and bluegills were abundant, pumpkinseed and black crappie were present, and yellow perch and white suckers were scarce.

Soils directly around Friendship Lake tend to be sands of various slopes. Those in the surface and ground watersheds are more loamy sands than straight sands. Such soils tend to be excessively-drained, with infiltration of water being rapid to very rapid, and permeability also high. Such soils also usually have a low water-holding and low organic matter content, thus making them difficult to establish vegetation on. These soils tend to be easily eroded by both water and wind.

Efforts at controlling aquatic plant growth have included both chemical treatments and mechanical harvesting.

	CHEMICAL TREATMENTS		
	Arsenic	Diquat	Rodeo
	Trioxide (lbs)	(oz)	(oz)
1960	7160		
1961	3240		
1885			24
1996		8	16
total	10,400 lbs	8 oz	40 oz

The arsenic treatments were lake-wide treatments. Arsenic stays in the sediments, resulting in the necessity to treat these lake sediments as hazardous waste. The Diquat & Rodeo treatments in 1995-1996 were conducted at a single shoreline site east of the bridge on the north shore.

In 1992, because of reports that aquatic plant growth was "solid" over more than one-half the lake, the Friendship Lake District applied for a grant to purchase a harvester. Mechanical harvesting started in 1993 and continued through 2006. An additional harvester was also obtained since 1993.

	Loads Removed	Avg Wgt of Load (lbs)	Total Removal (lbs)
1993	92	2500	230,000
1994	78	2500	195,000
1995	73	2500	182, 500
1998	130	2500	325,000
1999	209	2500	522,500
2000	223	2500	557,500
2001	299	2533	757,500
2002	262	1575	412,650
2003	300	1575	472,500
2004	234	2774	649,080
2005	466	2710	1,261,920
2006	Info not yet	available	
total	2366 loads		5,383,650 lbs

The first aquatic plant survey was by DNR staff in 1956. This qualitative survey showed that *Ceratophyllum demersum* (coontail) and *Brasenia scherberi* (watershield) were abundant; white and yellow water lilies, as well as *Potamogeton amplifolius* (large-leaf pondweed), *Vallisneria americana* (water celery), and *Potamogeton filimormia* (thread-leaf pondweed) were common. *Lemna minor, Elodea canadensis* and watermilfoil were present, but scarce.

Another qualitative survey was conducted in 1980. Abundant were coontail, cattail, milfoil, water celery, sedges, burreeds, and filamentous algae. Common were *Elodea canadensis* (waterweed), *Potamogeton natans* (floating-leaf pondweed), *Potamogeton zosteriformis* (flat-stem pondweed), *Najas flexilis* (bushy pondweed), and *Iris versicolor* (blue-flat iris). Also present were *Asclepias incarnata* (swamp milkweed), burreed, *Zosterella dubia (*water stargrass), duckweed, water lily and large-leaf pondweed.

The first quantitative vegetation survey of Friendship Lake was completed by WDNR staff and members of the Friendship Lake District in July 2003. At that time, 15 species of aquatic vegetation were found; none were emergent. The highest frequency and density of aquatic plants was in the 1.5'-5' depth zone (Zone 2). The exotic invasive, *Myriophyllum spicatum* (Eurasian watermilfoil) was found, but did not have a high frequency or density.

II. METHODS

Field Methods

The study was based on the rake-sampling method developed by Jessen and Lound (1962), using stratified random transects. The shoreline was divided into

19 equal sections, with one transect placed randomly within each segment, perpendicular to the shoreline.

One sampling site was randomly chosen in each depth zone (0-1.5'; 1.5'-5'; 5'-10'; 10'-20') along each transect. Using long-handled, steel thatching rakes, four rake samples were taken at each site. Samples were taken from each quarter around the boat. Aquatic species present on each rake were recorded and given a density rating of 0-5.

A rating of 1 indicates the species was present on 1 rake sample.

A rating of 2 indicates the species was present on 2 rake samples.

A rating of 3 indicates the species was present on 3 rake samples.

A rating of 4 indicates the species was present on 4 rake samples.

A rating of 5 indicates that the species was abundantly present on all rake samples.

A visual inspection and periodic samples were taken between transects to record the presence of any species that didn't occur at the raking sites. Gleason and Cronquist (1991) nomenclature was used in recording plants found.

Shoreline type was also recorded at each transect. Visual inspection was made of 50' to the right and left of the boat along the shoreline, 35' back from the shore (so total view was 100' x 35'). Percent of land use within this rectangle was visually estimated and recorded.

Data Analysis:

The percent frequency (number of sampling sites at which it occurred/total number of sampling sites) of each species was calculated. (See Appendix A) Relative frequency (number of species occurrences/total all species occurrences) was also determined. (See Appendix A) The mean density (sum of species' density rating/number of sampling sites) was calculated for each species. (See Appendix B) Relative density (sum of species' density/total plant density) was also determined. (See Appendix B) Mean density where present (sum of species' density rating/number of sampling sites at which species occurred) was calculated. (See Appendix B) Relative frequency and relative density results were summed to obtain a dominance value. (See Appendix C) Species diversity was measured by Simpson's Diversity Index. (See Appendix A)

The Average Coefficient of Conservatism and Floristic Quality Index were calculated as outlined by Nichols (1998) to measure plant community disturbance. A coefficient of Conservatism is an assigned value between 0 and 10 that measures the probability that the species will occur in an undisturbed habitat. The Average Coefficient of Conservatismism is the mean of the coefficients for the species found in the lake. The coefficient of conservatism is used to calculate the Floristic Quality Index, a measure of a plant community's closeness to an undisturbed condition.

An Aquatic Macrophyte Index was determined using the method developed by Nichols et al (2000). This measurement looks at the following seven parameters and assigns each of them a number on a scale of 1-10: maximum depth of plant growth; percentage of littoral zone vegetated; Simpson's diversity index; relative

frequency of submersed species; relative frequency of sensitive species; taxa number; and relative frequency of exotic species. The average total for the North Central Hardwoods lakes and impoundments is between 48 and 57.

III. RESULTS

Physical Data

The aquatic plant community can be impacted by several physical parameters. Water quality, including nutrients, algae and clarity, influence the plant community; the plant community in turn can modify these boundaries. Lake morphology, sediment composition and shoreline use also affect the plant community.

The trophic state of a lake is a classification of water quality (see Table 1). Phosphorus concentration, chlorophyll a concentration and water clarity data are collected and combined to determine a trophic state. **Eutrophic lakes** are very productive, with high nutrient levels and large biomass presence. **Oligotrophic lakes** are those low in nutrients with limited plant growth and small fisheries. **Mesotrophic lakes** are those in between, i.e., those which have increased production over oligotrophic lakes, but less than eutrophic lakes; those with more biomass than oligotrophic lakes, but less than eutrophic lakes; those with a good and more varied fishery than either the eutrophic or oligotrophic lakes.

The limiting factor in most Wisconsin lakes, including Friendship Lake, is phosphorus. Measuring the phosphorus in a lake system thus provides an indication of the nutrient level in a lake. Increased phosphorus in a lake will feed algal blooms and also may cause excess plant growth. **The 2004-2006 summer**

average phosphorus concentration in Friendship Lake was 16.02 ug/ml. This is below the average for impoundments lakes. This concentration suggests that Friendship Lake is likely to have some nuisance algal blooms, but not as frequently as many impoundments. This places Friendship Lake in the "good" water quality section for impoundments, and in the "**mesotrophic**" level for phosphorus.

Chlorophyll concentrations provide a measurement of the amount of algae in a lake's water. Algae are natural and essential in lakes, but high algal populations can increase water turbidity and reduce light available for plant growth. **The 2004-2006 summer average chlorophyll concentration in Friendship Lake was 2.02 ug/ml.** These low phosphorus results place Friendship Lake at the "oligotrophic" level for chlorophyll a results.

Water clarity is a critical factor for plants. If plants receive less than 2% of the surface illumination, they won't survive. Water clarity can be reduced by turbidity (suspended materials such as algae and silt) and dissolved organic chemicals that color or cloud the water. Water clarity is measured with a Secchi disk. **Average summer Secchi disk clarity in Friendship Lake in 2004-2006 was 9.3'.** This is very good water clarity, putting Friendship Lake into the "oligotrophic" category for water clarity.

It is normal for all of these values to fluctuate during a growing season. They can be affected by human use of the lake, by summer temperature variations, by algae growth & turbidity, and by rain or wind events. Phosphorus tends to rise in early summer, than decline as late summer and fall progress. Chlorophyll a tends to rise in level as the water warms, then decline as autumn cools the water. Water clarity

also tends to decrease as summer progresses, probably due to algae growth, then increase as fall approaches.

Table 1: Trophic States

Trophic State	Quality Index	Phosphorus (ug/ml)	Chlorophyll a (ug/ml)	Sechhi Disk (ft)
Oligotrophic	Excellent	<1	<1	>19
	Very Good	1 to 10	**1 to 5**	**8 to 19**
Mesotrophic	Good	**10 to 30**	5 to 10	6 to 8
	Fair	30 to 50	10 to 15	5 to 6
Eutrophic	Poor	50 to 150	15 to 30	3 to 4
Friendship Lake		**16.02**	**2.02**	**9.3'**

According to the 2004-2006 results, Friendship Lake scores as **"mesotrophic"** in its phosphorus level, and "**oligotrophi**c" in chlorophyll a readings, and Secchi disk readings. With such phosphorus readings and chlorophyll a readings, dense plant growth and frequent algal blooms would not be expected.

Lake morphology is an important factor in distribution of lake plants. Duarte & Kalff (1986) determined that the slope of a littoral zone could explain 72% of the observed variability in the growth of submerged plants. Gentle slopes support higher plant growth than steep slopes (Engel 1985).

Friendship Lake is a narrow, shallow lake fed by a large stream system. Most of the lake is shallow, although there are a couple of areas of steeper slopes within the lake near the dam. With very good water clarity and shallow depths, plant growth may be favored in Friendship Lake, since the sun can get to most of the sediment to stimulate plant growth.

Sediment composition can also affect plant growth, especially those rooted. The richness or sterility and texture of the sediment will determine the type and abundance of macrophyte species that can survive in a particular lake (see Table 2 and Appendix A).

Table 2: Sediment Composition—Friendship Lake

Sediment	Type	Zone 1	Zone 2	Zone 3	Zone 4	Overall
Hard	Gravel	10.53%				3.17%
	Sand	31.58%	31.58%	56.25%	100.00%	47.62%
	SandCobble	5.26%				1.59%
Mixed	Sand/Muck	5.26%	5.27%			3.17%
	Sand/Peat	5.27%				1.59%
Soft	Muck	36.84%	57.89%	25.00%		34.92%
	Peat	5.26%		12.50%		3.17%
	Silt		5.26%	6.25%		4.76%

Over 47% of the sediment in Friendship Lake is soft with natural fertility and significant available water holding capacity. Although sand sediment may limit growth, all sandy sites in Friendship Lake were vegetated. In fact, 88.9% sample sites were vegetated in Friendship Lake, no matter what the sediment (see Appendix G).

Shoreline land use often strongly impacts the aquatic plant community and thus the entire aquatic community. Impacts can be caused by increased erosion and sedimentation and higher run-off of nutrients, fertilizers and toxins applied to the land. Such impacts occur in both rural and residential settings.

Native herbaceous vegetation was the shoreline cover with highest percent (65.38%) (see Table 3). But disturbed sites, such as those with traditional lawn,

rock/riprap, hard structures and pavement, were also frequent, covering over 23% of the shoreline (20.72%). Bare unprotected soil was found (2.31%).

Table 3: Shoreland Land Use—FriendshipLake

	Type	Frequency	Coverage
Vegetated	Herbaceous	89.47%	28.16%
Shoreline	Shrub	63.16%	14.74%
	Wooded	89.47%	32.89%
Disturbed	Bare soil	5.26%	0.53%
Shoreline	Erosion	1.58%	3.95%
	Cultivated Lawn	15.79%	5.53%
	Hard Structure	63.16%	10.00%
	Pavement/Riprap	7.37%	4.20%

Some type of native vegetated shoreline was found at 92.74%% of the sites and covered 75.29% of the lake shoreline.

Macrophyte Data

SPECIES PRESENT

Of the 36 species found in Friendship Lake, 33 were native and 3 were exotic invasives. In the native plant category, 19 were emergent, 3 were free-floating plants, 1 was floating-leaf rooted, and 13 were submergent types (see Table 4). Three exotic invasives, *Myriophyllum spicatum* (Eurasian Watermilfoil), *Phalaris arundinacea* (Reed Canarygrass) and *Potamogeton crispus* (Curly-Leaf Pondweed) were found.

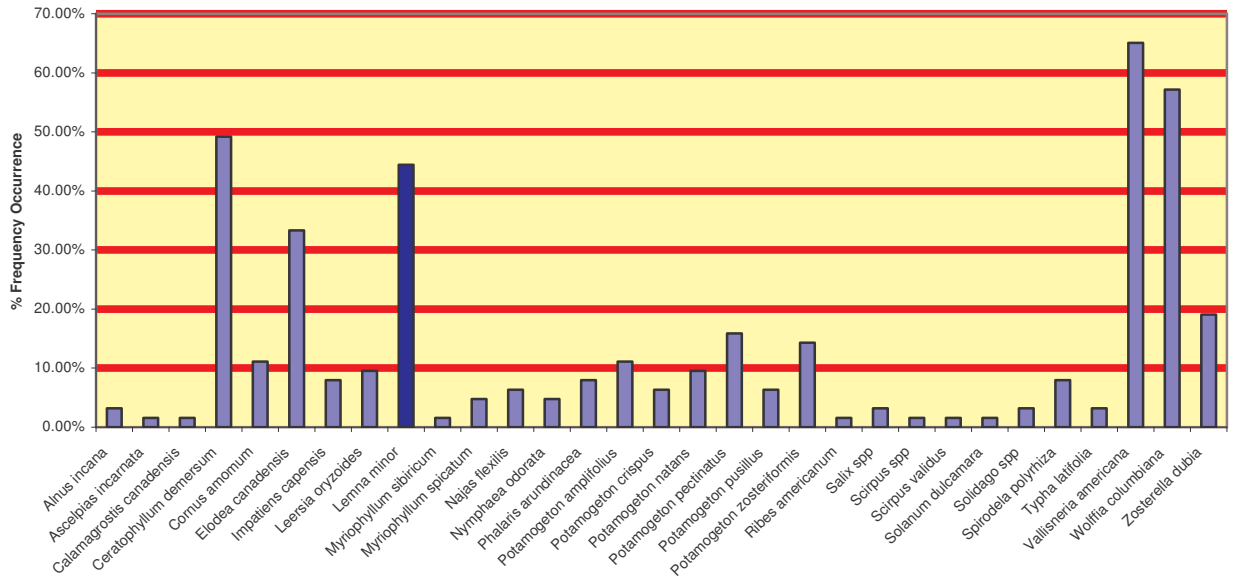
Table 4—Plants Found in Friendship Lake, 2006

Scientific Name	Common Name	Type
Alnus incana	Tag Alder	Emergent
Ascelpias incarnata	Swamp Milkweed	Emergent
Calamagrostis canadensis	Blue-Joint Grass	Emergent
Ceratophyllum demersum	Coontail	Submergent
Circuita bulbifera	Water Hemlock	Emergent
Cornus amomum	Silky Dogwood	Emergent
Elodea canadensis	Waterweed	Submergent
Impatiens capensis	Jewelweed	Emergent
Iris versicolor	Blue-Flag Iris	Emergent
Leersia oryzoides	Rice-Cut Grass	Emergent
Lemna minor	Lesser Duckweed	Free-Floating
Myriophyllum sibiricum	Northern Milfoil	Submergent
Myriophyllum spicatum	Eurasian Watermilfoil	Submergent
Najas flexilis	Bushy Pondweed	Submergent
Nymphaea odorata	White Water Lily	Floating-Leaf
Phalaris arundinacea	Reed Canarygrass	Emergent
Potamogeton amplifolius	Large-Leaf Pondweed	Submergent
Potamogeton crispus	Curly-Leaf Pondweed	Submergent
Potamogeton natans	Floating-Leaf Pondweed	Submergent
Potamogeton pectinatus	Sago Pondweed	Submergent
Potamogeton pusillus	Small Pondweed	Submergent
Potamogeton zosteriformis	Flat-Stemmed Pondweed	Submergent
Ribes americanum	Wild Currant	Emergent
Rumex spp	Water Dock	Emergent
Salix spp	Willow spp	Emergent
Scirpus spp	Bulrush	Emergent
Scirpus cyperinus	Woolgrass	Emergent
Scirpus microcarpus	Panicled Bulrush	Emergent
Scirpus validus	Soft-Stem Bulrush	Emergent
Solanum dulcamara	Nightshade	Emergent
Solidago spp	Goldenrod	Emergent
Spirodela polyrhiza	Greater Duckweed	Free-Floating
Typha latifolia	Narrow-Leaf Cattail	Emergent
Vallisneria americana	Water Celeery	Submergent
Wolffia columbiana	Watermeal	Free-Floating
Zosterella dubia	Water Stargrass	Submergent

FREQUENCY OF OCCURRENCE

Vallisnera americana was the most frequently-occurring plant in Friendship Lake in 2006 (64.08% frequency), followed by *Wolffia columbiana* (57.14%%). No other species reached a frequency of 50% or greater, although *Ceratophyllum demersum* and *Lemna minor* were not far below 50% frequency, with 49.21% and 44.44% frequency respectively.

Chart 1: Occurrence Frequency



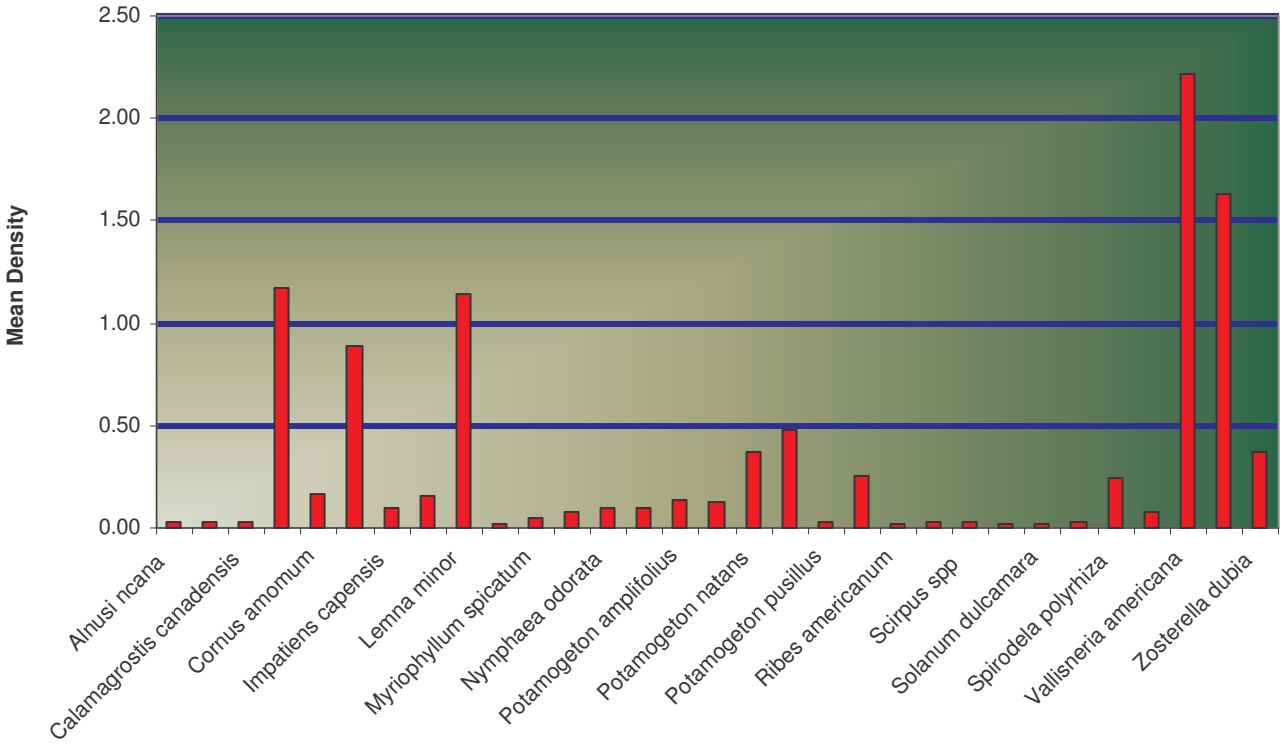
Filamentous algae was found at 100% of the sample sites.

DENSITY OF OCCURRENCE

Vallisneria americana was also the densest plant in Friendship Lake, with a mean density of 2.22. Somewhat less dense plants were *Wolffia columbiana* (1.63), *Ceratophyllum demersum* (1.17), and *Lemna minor* (1.14). Only *Vallisneria*

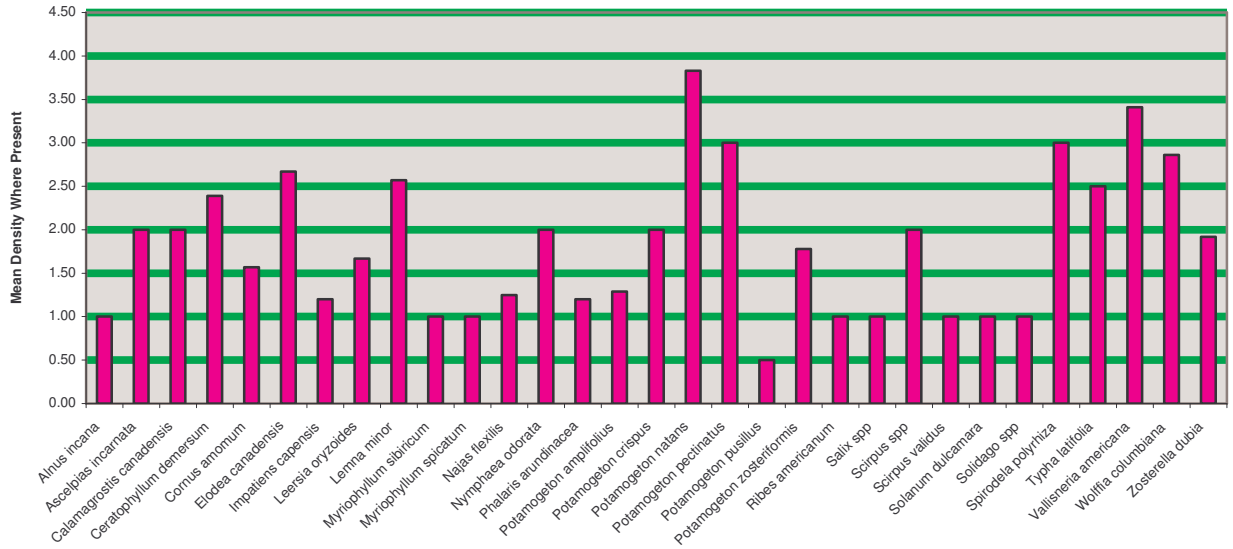
americana had a mean density over 2.0, meaning only that plant grew at more than average density in the lake overall. *Wolffia columbiana* (2.28) and *Vallisneria americana* (2.06) occurred at more than average density in Depth Zone 1 (0-1.5'), as they did in Depth Zone 2 (1.5'-5') with mean densities in that zone of 2.58 (*Vallisneria americana)* and 2.16 *(Wolffia columbiana).* Only *Vallisneria americana* (3.13) occurred at more than average density in Depth Zone 2 (1.5'-5'). There were no species at above average density in Depth Zone 4 (10'-20').

Chart 2: Occurrence Density



Density changes when analyzing the figures of "mean density where present". Using these calculations, more plants are found at greater than average density. Although *Ceratophyllum demersum* (2.39), *Vallisneria americana* (3.41) and *Wolffia columbiana* (2.86) still had greater than average density, several plants are added to the list of having more than average density: *Potamogeton natan* (3.83), *Potamogeton pectinatus* (3.00), *Spirodela polyrhiza* (3.00) and *Typha latifolia* (2.50).

Chart 2a: Mean Density Where Present

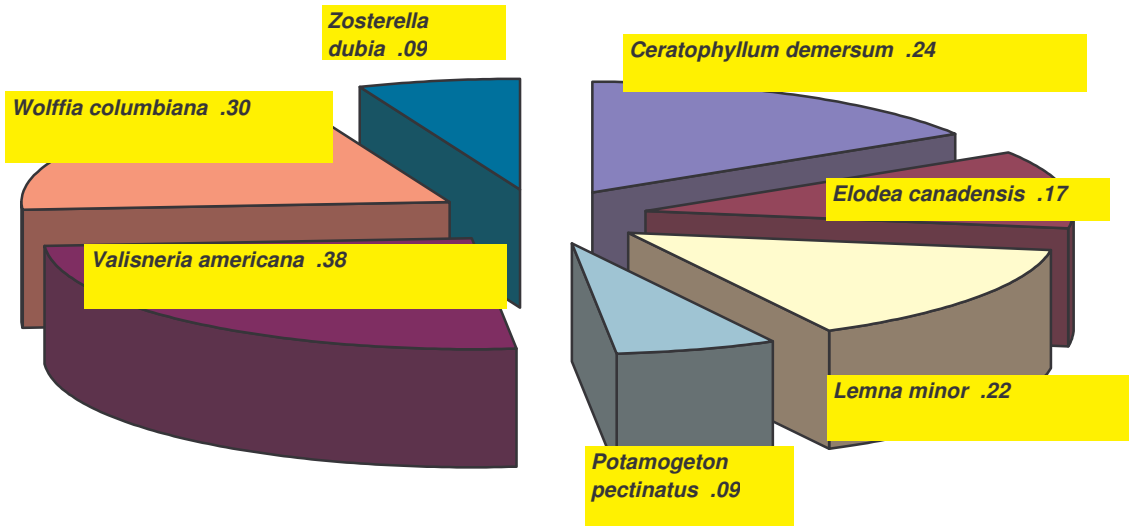


DOMINANCE

Relative frequency and relative density are combined into a dominance value that demonstrates how dominant a species is within its aquatic plant community. Based on dominance value, *Vallisneria americana* was the dominant aquatic plant species in Friendship Lake. Sub-dominant were *Wolffia Columbiana, Ceratophyllum demersum* and *Lemna minor. Myriophyllum spicatum,*

Potamogeton crispus and *Phalaris arundinacea*, the exotics found Friendship Lake, were not present in high frequency, high density or high dominance. It is possible that *Potamogeton crispus* is under-represented, since this survey was performed in August, somewhat later than its peak season.

Chart 3: Dominance



Wolffia columbiana was dominant in 0-1.5' depth zone, with *Vallisneria americana* sub-dominant. *Wolffia columbiana also* dominated the 1.5'-5.0' depth zone, with *Vallisneria americana* and *Lemna minor* sub-dominant. *Vallisneria americana* was dominant in the depth zone of 5'-10' and of 10'-20'; *Wolffia columbiana* was sub-dominant in Depth Zone 4.

DISTRIBUTION

Aquatic plants occurred at 89% of the sample sites in Friendship Lake to a maximum rooting depth of 12'. Free-floating plants were found in all four depth zones (see Appendix B, as was filamentous algae.

Secchi disc readings are used to predict maximum rooting depth for plants in a lake (Dunst, 1982). Based on the summer 2004-2006 Secchi disc readings, the predicted maximum rooting depth in Friendship Lake would be **14.08 feet.** During the 2006 aquatic plant survey, rooted plants were found at a depth of **12'**, i.e., rooted plants were at a depth less to that to be expected by Dunst calculations. Rakes at 13.5' produced no plants.

The 0-1.5' depth zone (Zone 1) produced the most frequently occurring plant growth. There was a sharp drop to frequency in Zone 2 (1.5'-5'), then another frequency drop to Zone 3 (5'-10'), and a final sharp drop in plant frequency in Zone 4 (over 10'). The same order was followed with aquatic plant density.

Chart 4: Zone Frequency

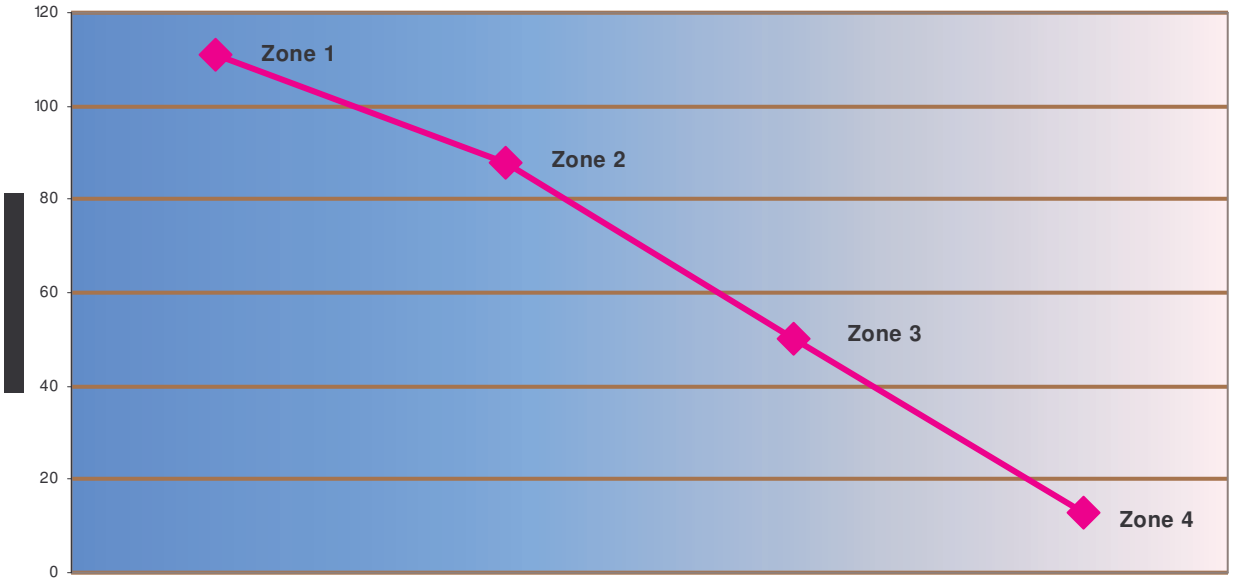
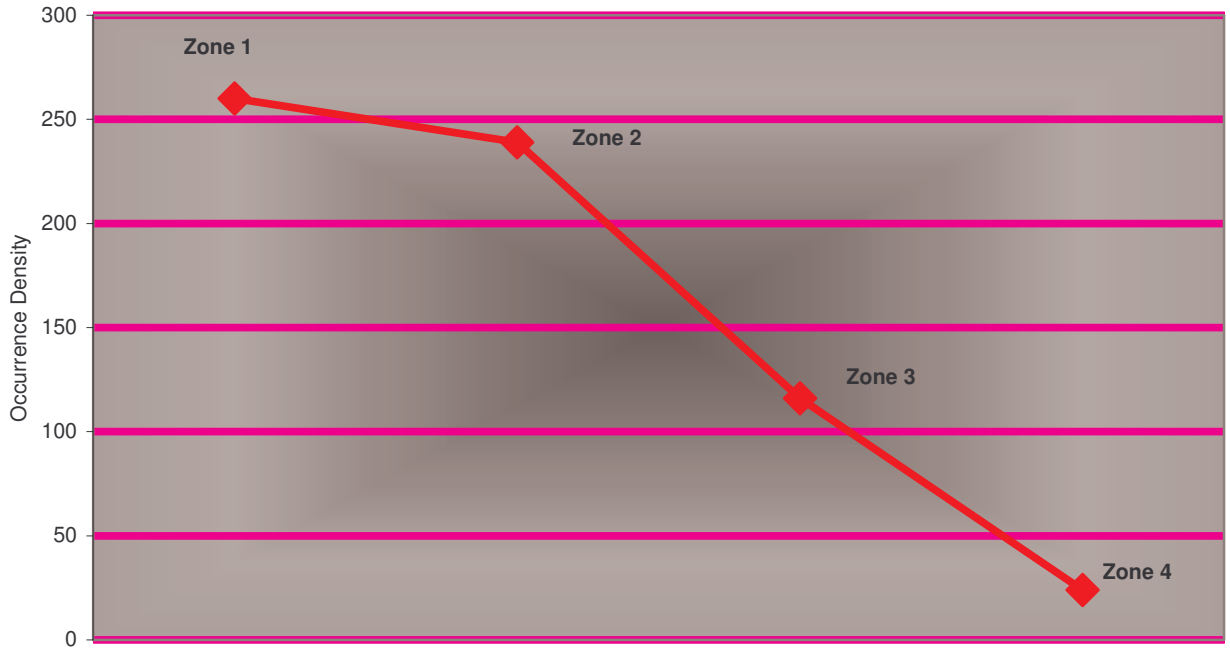


Chart 5: Zone Density



The greatest number of species per site (species richness) was found in Zone 1 with 6.17 species richness. A sharp drop was found in Zone 2 and Zone 3, with species richness of 4.63 and 3.33 respectively. Zone 4 species richness was 3.25. Overall species richness was 4.69.

THE COMMUNITY

The Simpson's Diversity Index Friendship Lake was .92, very good species diversity. A rating of 1.0 would mean that each plant in the lake was a different species (the most diversity achievable). This places it in the upper quartile for Simpson's Diversity Index readings for both North Central Hardwood Forest and all Wisconsin lakes. The AMCI for Friendship Lake is 53, placing it in the average range for North Central Wisconsin Lakes and all Wisconsin Lakes.

Table 5: Aquatic Macrophyte Community Index-2006

Aquatic Macrophyte Community Index for Friendship Lake 2006		
Category	Friendship Lake results	Value
Maximum rooting depth	12.5'	7
% littoral area vegetated	89%	10
%submersed plants	60%	6
% sensitive plants	6%	5
# taxa found	33 (3 exotic)	10
exotic species frequency	5%	6
Simpon's Diversity	.92	9
total		**53**

The presence of several invasive, exotic species could be a significant factor in the future. Currently, none of the exotic species appear to be taking over the aquatic plant community, perhaps due to the high density and occurrence of other native

plants such as *Elodea canadensis. Myriophyllum spicatum* (Eurasian watermilfoil) should be monitored, since its tenacity and ability to spread to large areas fairly quickly could make it a danger to the diversity of Friendship Lake's already limited aquatic plant community.

A Coefficient of Conservatism and a Floristic Index calculation were performed on the field results. Technically, the average Coefficient of Conservatism measures the community's sensitivity to disturbance, while the Floristic Index measures the community's closeness to an undisturbed condition. Indirectly, they measure past and/or current disturbance to the particular community.

Previously, a value was assigned to all plants known in Wisconsin to categorize their probability of occurring in an undisturbed habitat. This value is called the plant's Coefficient of Conservatism. A score of 0 indicates a native or alien opportunistic invasive plant. Plants with a value of 1 to 3 are widespread native plants. Values of 4 to 6 describe native plants found most commonly in early successional ecosystem. Plants scoring 6 to 8 are native plants found in stable climax conditions. Finally, plants with a value of 9 or 10 are native plants found in areas of high quality and are often endangered or threatened. In other words, the lower the numerical value a plant has, the more likely it is to be found in disturbed areas.

The Average Coefficient of Conservatism in Friendship Lake in 2006 was 4.15. This puts it in the lowest quartile for Wisconsin Lakes (6.0) and for lakes in the North Central Hardwood Region (5.6). The aquatic plant community in Friendship Lake is in the category of those very tolerant of disturbance, probably due to selection by a series of past disturbances.

The Floristic Quality Index of the aquatic plant community in Friendship Lake of 23.85 is slightly above average for Wisconsin Lakes (22.2) and the North Central Hardwood Region (20.9). This suggests that the plant community in Friendship Lake is closer to an undisturbed condition than the average lake in Wisconsin overall and in the North Central Hardwood Region. Using either scale, the aquatic plant community in Friendship Lake has impacted by at least an average amount of disturbance.

"Disturbance" is a term that covers many disruptions to a natural community. It includes physical disturbances to plant beds such as boat traffic, plant harvesting, chemical treatments, dock and other structure placements, shoreline development and fluctuating water levels. Indirect disturbances like sedimentation, erosion, increased algal growth, and other water quality impacts will also negatively affect an aquatic plant community. Biological disturbances such as the introduction of non-native and/or invasive species (such as the Eurasian Watermilfoil, Reed Canarygrass and Curly-Leaf Pondweed found here), destruction of plant beds, or changes in aquatic wildlife can also negatively impact an aquatic plant community. Shore development and sediment deposition can also reduce the quality of the aquatic plant community.

Some of the sample transects had an entirely native shore, although more sites had some disturbance by humans.

	Natural	Disturbed
Number of species	25	30
FQI	22.4	23.92
Average Coef. Of Cons	4.48	4.37
Simpson's Index	0.93	0.89
AMCI	51	50
Filamentous algae	100%	100%

Analyzing data from the disturbed shores vs natural shores, the disturbed shores actually had higher scores for FQI and species number, but the natural shores have a higher coefficient of Conservatism, higher Simpson's Diversity Index, and higher Aquatic Macrophyte Community Index. The high amount of disturbance in the lake overall probably explains this variety of differentiation between natural and disturbed shores.

IV. DISCUSSION

Based on water clarity, chlorophyll and phosphorus data, Friendship Lake is a mesotrophic impoundment lake with very good water clarity and good to very good water quality. This trophic state should support moderate plant growth and occasional algal blooms.

Sufficient nutrients (trophic state), fair water clarity, shallow lake, and soft sediments at Friendship Lake favor plant growth. Despite the sometime limiting effect of sand sediments on aquatic plant growth, 89% of the lake is vegetated, suggesting that even the sand sediments in Friendship Lake hold sufficient nutrients to maintain aquatic plant growth.

Past aquatic plant control in Friendship Lake were both chemical and mechanical. There appear has been mechanical harvesting to try to reduce nuisance plant

growth in the last 12 years or so. A continued regular schedule and pattern of machine harvesting could help in removing vegetation from the lake and may somewhat help with nutrient reduction. The harvesting should also be designed to set back the growth of Eurasian Watermilfoil, not spread it further. It might also help to skim off the high density of filamentous algae and floating-leaf plants.

The lake does have a mixture of emergent, free-floating, floating-leaf and submerged plants. Of the 36 specific species found in Friendship Lake, 33 were native and 3 were exotic invasives. In the native plant category, 18 were emergent, 3 were free-floating plants, 1 was floating-leaf rooted, and 11 were submergent types (see Table 4). Three exotic invasives, *Myriophyllum spicatum* (Eurasian Watermilfoil), *Phalaris arundinacea* (Reed Canarygrass) and *Potamogeton crispus* (Curly-Leaf Pondweed) were found.

Vallisnera americana was the most frequently-occurring plant in Friendship Lake in 2006 (64.08% frequency), followed by *Wolffia columbiana* (57.14%%). No other species reached a frequency of 50% or greater, although *Ceratophyllum demersum* and *Lemna minor* were not far below 50% frequency, with 49.21% and 44.44% frequency respectively.

Vallisneria americana was also the densest plant in Friendship Lake, with a mean density of 2.22. Somewhat less dense plants were *Wolffia columbiana* (1.63), *Ceratophyllum demersum* (1.17), and *Lemna minor* (1.14). Only *Vallisneria americana* had a mean density over 2.0, meaning only that plant grew at more than average density in the lake overall. *Wolffia columbiana* (2.28) and *Vallisneria americana* (2.06) occurred at more than average density in Depth Zone 1 (0-1.5'), as they did in Depth Zone 2 (1.5'-5') with mean densities in that

zone of 2.58 (*Vallisneria americana)* and 2.16 *(Wolffia columbiana).* Only *Vallisneria americana* (3.13) occurred at more than average density in Depth Zone 2 (1.5'-5'). There were no species at above average density in Depth Zone 4 (10'-20').

There areas of wooded and wetland shores on the most of the shore of the lake should be preserved as they are to maintain habitat and to serve as a buffer for that area. Studies have suggested that runoff from establish wooded land is substantially less than that of developed areas. There are also some areas of deep erosion on steep banks that need to be addressed to present tree fall (and related root ball removal from bank) and bank preservation.

The Simpson's Diversity Index Friendship Lake was .92, very good species diversity. A rating of 1.0 would mean that each plant in the lake was a different species (the most diversity achievable). This places it in the upper quartile for Simpson's Diversity Index readings for both North Central Hardwood Forest and all Wisconsin lakes. The AMCI for Friendship Lake is 53, placing it in the average range for North Central Wisconsin Lakes and all Wisconsin Lakes.

Some kind of native vegetation was the dominant shore cover in Friendship Lake (total of 75.79%). However, disturbed sites, such as those with bare soil, cultivated lawn, hard structure, rock/riprap and pavement, were also common, with coverage of nearly 23%. Of vegetated shorelines, wooded vegetation had the most coverage (32.89%). Some type of disturbed shoreline was found at 79% of the sites. These conditions offer little protection for water quality and have significant potential to negatively impact Friendship Lake's water by increased runoff (including lawn fertilizers, pet waste, pesticides) and shore erosion.

An aquatic plant community evaluation was conducted on Friendship Lake in 2002. Comparing the results of the two evaluations and the limited information from the 1991 and 1979 surveys, there are some changes in the aquatic plant community.

	2006	2002	1992	1979
Number of species	33	15	13	17
FQI	23.85	18.85	14.98	20.86
Average Coef. Of Cons	4.87	4.15	4.15	5.06
Simpson's Index	0.92	0.86	NA	NA
AMCI	53	41	NA	NA
Species Richness	4.68	3.08	NA	NA

Most of the new plants found in 2006 were emergent plants: *Alnus incana, Asclepias incarnata, Calamogrostis canadensis, Impatiens capensis, Leersia oryzoides, Ribes americanum, Salix spp, Scirpus spp, Scirpus validus, Solanum duclamara, Solidago spp, and Typha latifolia*. Also new in 2006 was *Spirodela polyrhiza, Potamogeton pectinatus*, *Phalaris arundinacea* (an exotic invasive) and *Wolffia columbiana*, a free-floating plant.

Several plants went down in frequency of occurrence: *Potamogeton pusillus* decreased in frequency of occurrence, as did *Elodea canadensis, Nymphaea odorata, Potamogeton crispus* (an invasive exotic), *Myriphyllum sibiricum* and *Myriophyllum spicatum* (an exotic invasive). *Ranunculus longirostris*, found in 2002, was not found in 2006.

Some plants went up in frequency of occurrence. *Zosterella dubia, Vallisneria americana, Potamogeton zosteriformis, Potamogeton natans, Potamogeton amplifolius, Najas flexilis, Lemna minor* and *Ceratophyllum demersum.*

The AMCI is up from 2003, but the Average Coefficient of Conservatism is lower, as low as it was in 1992. Species Richness and the Floristic Quality Index went up between 2002 and 2006, as did the Simpson's Index of Diversity. But the Floristic Quality Index in 1979 was between the 2002 and 2006 scores. It appears, even using the limited information from 1979 and 1992, that flux in these figures may not necessarily indicate an ongoing increase in the quality of the aquatic plant community.

Further, when calculating the coefficient of similarity between the 2002 and 2006 surveys, they score as statistically dissimilar. Based on frequency of occurrence, the aquatic plant communities of the two years are only 62% similar. Based on relative frequency, they are 41% similar. Similarity percentages of 75% are considered statistically similar; obviously, Friendship Lake percentages are far from that.

It is worth noting that the report on the 2002 aquatic plant surveys mentioned the absence of emergent plants in Friendship Lake. The 2006 survey shows that emergent plants are "coming back", i.e., are re-establishing in Friendship Lake.

However, one point of concern is the reduced frequency of occurrence of *Nymphaea odorota* by about one-half. The water-lilies are needed as habitat, feeding and cover areas for many species. An additional issue is the new and substantial presence of free-floating plants like *Lemna minor, Spirodela polyrhiza*

and *Wolffia columbiana.* The high frequency and density of such species suggests a significant nutrient increase in the waters of Friendship Lake.

Friendship	2002	2006	Change	%Change
Number of Species	15	**33**	18	120.0%
Maximum Rooting Depth	10.0	**12.5**	3	25.0%
% of Littoral Zone Unvegetated	**16.70%**	11.10%	-0.056	-33.5%
%Sites/Emergents	0.00%	23.21%	0.2	23.2%
%Sites/Free-floating	10.00%	76.79%	0.7	667.9%
%Sites/Submergents	100.00%	96.43%	0.0	-3.6%
%Sites/Floating-leaf	10.00%	5.36%	0.0	-46.4%
Simpson's Diversity Index	0.86	**0.92**	0.06	7.0%
Species Richness	3.08	**4.68**	1.60	51.9%
Floristic Quality	18.85	**23.85**	5.00	26.5%
Average Coefficient of Conservatism	**4.87**	4.15	-0.72	-14.8%
AMCI Index	41	**53**	16.00	39.0%

V. CONCLUSIONS

Friendship Lake is a mesotrophic to oligotrophic impoundment with good water quality and good to very good water clarity. The Coefficient of Conservatism average of the aquatic plant community in Friendship Lake is below average for Wisconsin lakes and for lakes in the North Central Hardwood region, but above the average for Floristic Quality. The AMCI is in the average range for both North Central Hardwood Region and all Wisconsin lakes. Filamentous algae is

abundant. Structurally, the aquatic plant community contains emergent plants, free-floating plants, floating-leaf rooted plants and submergent plants.

When the aquatic plant survey was performed in 2006, 89% of the littoral zone was vegetated. The potential for plant growth at all depths of the lake is present, even though a few of the lake sediments are sandy. This growth percent is slightly over the recommended vegetation percentage for best fishing (50%-85%).

Vallisnera americana was the most frequently-occurring plant in Friendship Lake in 2006 (64.08% frequency), followed by *Wolffia columbiana* (57.14%%). No other species reached a frequency of 50% or greater, although *Ceratophyllum demersum* and *Lemna minor* were not far below 50% frequency, with 49.21% and 44.44% frequency respectively.

Vallisneria americana was also the densest plant in Friendship Lake, with a mean density of 2.22. Somewhat less dense plants were *Wolffia columbiana* (1.63), *Ceratophyllum demersum* (1.17), and *Lemna minor* (1.14). Only *Vallisneria americana* had a mean density over 2.0, meaning only that plant grew at more than average density in the lake overall. *Wolffia columbiana* (2.28) and *Vallisneria americana* (2.06) occurred at more than average density in Depth Zone 1 (0-1.5'), as they did in Depth Zone 2 (1.5'-5') with mean densities in that zone of 2.58 (*Vallisneria americana)* and 2.16 *(Wolffia columbiana).* Only *Vallisneria americana* (3.13) occurred at more than average density in Depth Zone 2 (1.5'-5'). There were no species at above average density in Depth Zone 4 (10'-20').

A healthy and diverse aquatic plant community plays a vital role within the lake ecosystem. Plants help improve water quality by trapping nutrients, debris and pollutants in the water body; by absorbing and/or breaking down some pollutants; by reducing shore erosion by decreasing wave action and stabilizing shorelines and lake bottoms; and by tying-up nutrients that would otherwise be available for algae blooms. Aquatic plants provide valuable habitat resources for fish and wildlife, often being the base level for the multi-level food chain in the lake ecosystem, and also produce oxygen needed by animals.

Further, a healthy and diverse aquatic plant community can better resist the invasion of species (native and non-native) that might otherwise "take over" and create a lower quality aquatic plant community. A well-established and diverse plant community of natives can help check the growth of more tolerant (and less desirable) plants that would otherwise crowd out some of the more sensitive species, thus reducing diversity.

Vegetated lake bottoms support larger and more diverse invertebrate populations that in turn support larger and more diverse fish and wildlife populations (Engel, 1985). Also, a mixed stand of aquatic macrophytes (plants) supports 3 to 8 times more invertebrates and fish than do monocultural stands (Engel, 1990). A diverse plant community creates more microhabitats for the preferences of more species.

MANAGEMENT RECOMMENDATIONS

(1) Because the plant cover in the littoral zone of Friendship Lake is over the ideal (25%-85%) coverage for balanced fishery, consideration should be given to reducing plant growth in at least some areas. A map of areas to have plants removed should be developed, then removal should occur by hand to be sure that entire plants are removed and to minimize the amount of disturbance to the settlement. However, harvesting should be avoided in areas of lily pads to prevent further reduction in their presence.

(2) Natural shoreline restoration and erosion control in some areas is needed, especially on some bare steep banks that are heavily wooded. If those trees fall due to continued erosion, large portions of the banks will fall with them.

(3) A buffer area of native plants should be restored on those sites that now have traditional lawns mowed to the water's edge.

(4) Stormwater management of the impervious surfaces around the lake is essential to maintain the high quality of the lake water. For example, a street and parking area runs near one very narrow point, resulting in runoff on both sides of the point.

(5) No lawn chemicals, especially lawn chemicals with phosphorus, should be used on properties around the lake. If they must be used, they should be used no closer than 50' to the shore.

(6) The aquatic plant management plan should be revised. The 2003 Report indicated that mechanical harvesting appeared to have reduced the amount of filamentous algae and the amount of Eurasian Watermilfoil (EWM) and Curly-leaf Pondweed (CLP). However, the 2006 survey found filamentous algae at all sites, although EWM and CLP continued to be down. The plan should consider including target harvesting for Eurasian Watermilfoil (EWM) to

prevent further spread, as well as avoiding sensitive areas and beds of lily pads.

(7) The Friendship Lake Association may want to apply for grants from the Wisconsin Department of Natural Resources to help defray the cost of aquatic plant management.

(8) No broad-scale chemical treatments of aquatic plant growth are recommended due to the undesirable side-effects of such treatments, including increased nutrients from decaying plant material and decreased dissolved oxygen and opening up more areas to the invasion of EWM.

(9) Fallen trees should be left at the shoreline.

(10) Friendship Lake has long participated in the Self-Help Monitoring Program through the WDNR with the help of Tom & Eva Steiskal. Continued participation is recommended.

(11)Friendship Lake residents should identify, cooperate with and participate in watershed programs that will reduce nutrient and sediment inputs.

(12)Critical habitat areas were formally determined in 2006, with a report due out later this year. A lake management plan should include preserving these areas.

(13) The areas where there is undisturbed wooded shore should be maintained and left undisturbed.

(14) The Friendship Lake District should make sure that its lake management plan that takes into account all inputs from both the surface and ground watersheds and addresses the concerns of this lake community.

(15) Cooperation with the Adams County Parks Department in keeping the boat ram and swimming beach in safe condition should help reduce any negative impacts caused by the heavy use of these public areas.

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